# PHILOSOPHICAL

# TRANSACTIONS.

X. *On some phenomena of colours, exhibited by thin plates. By* John Knox, *Esq. Communicated by the Right Hon. Sir Joseph Banks, Bart. G.C.B. P.R.S.*

Read April 6, 1815.

It is not without reason that the phenomena of light have been subjects of speculative enquiry from the earliest ages of philosophy; since perhaps no study can be more interesting to the inquisitive mind, than the contemplation of that medium through which it receives its most exalted enjoyments.

There are probably no appearances in physical optics that have excited more attention, and that have been less satisfactorily accounted for, than those prismatic concentric rings which appear between lenses, or between a flat glass and a lens, when laid together. And, notwithstanding some of the most eminent philosophers and opticians have given explanations thereof, particularly Sir Isaac Newton and Dr. Herschel, it will appear from what follows, that the subject is far from being exhausted.

The insufficiency of Newton's theory for the solution of this problem, by the supposed fits of easy transmission and

reflection of the rays of light, is now generally admitted; nor does it appear that any other more satisfactory, has yet been adopted in its stead.

This will not be thought surprising, if it shall appear by the following experiments, that neither NEWTON, nor any other writer that has followed him in the same line, has been in possession of all the phenomena connected with this curious and intricate subject.

I was induced to make the following experiments in consequence of having lately read Dr. HERSCHEL's excellent paper on the same subject, published in the 95th vol. of the Philosophical Transactions, in which he has related a great number of experiments, explaining a variety of phenomena relative to prismatic rings; and must acknowledge my obligations to this celebrated author, for his simple but ingenious contrivance of viewing prismatic phenomena by means of the shadow of a black card; without which, it is probable the following discoveries, such as they are, would not have been made.

*Exp.* 1. On repeating some of the experiments mentioned by Dr. HERSCHEL in vol. 95 of the Philosophical Transactions, and having by means of the shadow of a blackened card perceived no less than eight sets of rings in some cases, and being very attentive in endeavouring to distinguish transmitted from reflected sets, I faintly saw parallel lines or streaks, which at first were mistaken for the threads of a piece of black silk which was placed under the lower glass, in order to see the rings more distinctly. It was not until after repeated examinations by the light of a lamp, in which the direct light is shaded from the eyes, that it was ascertained,

that those parallel lines were drawn through the intersections made by the several rings of the primary set and its reflected image, and that they consisted of light, although their dimensions were too small for their colours to be distinctly perceived.

The apparatus used in this experiment was a piece of good looking-glass plate laid on the plane side of a plano-concave lens belonging to a compound microscope, and was used for holding mites or other animalcules on the concave side. The plane side of this glass had acquired in the polishing (accidentally perhaps) a very small degree of convexity, probably equal to that of a lens of several feet focal length. This lens, when the plane glass was laid thereon, produced a larger set of primary rings than could be otherwise procured. Its concave side had been ground on a sphere of about two inches radius; therefore the set of transmitted rings, reflected from its lower internal surface, was too small to cause any confusion either in the primary set or its reflected image; and it was in a great measure owing to this accidental circumstance, that these parallel lines happened to be discovered at all; nor could they have been discovered, even with this apparatus, without the use of the shadow.

*Exp.* 2. Having ascertained the reality of these parallel fringes, I painted the concave side of the plano-concave lens black, in order to prevent all reflection from its concave surface; by which means the fringes were seen in much greater perfection. They were found to consist of all the prismatic colours; were equidistant and parallel; equal in number to the rings of both sets taken together, exclusive of the central one; and each fringe was drawn through the several inter-

sections of the primary set of rings with those of its reflected image; and their lengths extended to the edge of the lens on both sides, they were formed at right angles to the direction of the light, and to a line joining the centres of the primary and its reflected image; which indeed is a necessary consequence of their being projected through the intersections of two sets of concentric rings perfectly equal in dimensions. See fig. 1, pl. VII. compared with fig. 3, pl. VIII.

I was convinced that those parallel fringes consisted of prismatic colours; yet with the apparatus now used, they were too small and too close to each other to enable me to perceive distinctly the order in which those colours were arranged, with respect to each other. As their distances from each other, or, which is the same thing, their breadths depended on the distances of the intersections through which they were projected; it was obvious that by separating, or widening the distances of the latter, the parallel fringes would also be separated, and consequently their breadths enlarged.

*Exp.* 3. For effecting this purpose, two modes presented themselves, either by increasing the dimensions of the primary set of rings, and consequently that of its reflected image; or by lessening the distance between them. The former mode was at that time out of my power, having no lens of a longer focus than the one in use. The latter was effected by procuring a thinner piece of plate glass than that used in the 1st experiment; and although by this apparatus the field of view was narrowed, the breadths of the fringes were enlarged, and by this means it was easily perceived, that each fringe was composed of the same prismatic colours as the Newtonian rings,

and were placed in the same order with respect to each other; that is, beginning with red, next orange, then yellow, green, blue, indigo, and lastly, violet: but that the fringes themselves were divided into two classes, (with respect to the position of the colours of each particular fringe) by a central band or fringe passing through a point bisecting the distances between the centres of the primary set and its image, each fringe, on both sides of this imaginary point, respecting it as a centre, and having the red colour of each fringe turned *outwards*, or from that centre; the central band alone being equal on both of its sides with respect to colour; being as it were composed of two of the inside halves of the two adjoining fringes, imagined to be laid together; having no red in its composition, and being rather less intense in colour than any of the others. An imitation is given in fig. 1. pl. VII. and as it would be impracticable to express all the colours of each fringe by shadowing, the darkest shade denotes the violet, the unshaded side the red of each fringe, and the black lines the divisions between them.

*Exp.* 4. Another mode of producing those fringes was by applying a convex and a concave lens together, the curvature of the one differing but little from that of the other. This apparatus produced a larger set of primary rings, and consequently broader fringes, than by either of the foregoing experiments; but in this case none of them were straight, except the central fringe, all the rest being bent more or less into elliptical shapes, conformable to the surfaces between which they were formed.

*Exp.* 5. But a better mode still was found, by applying a slip of looking-glass plate to one of the sides of a triangular

prism, about $5\frac{1}{2}$ inches long, and a full inch broad; for although the sides had been intended to be made perfectly flat, they had acquired, in polishing, such a small degree of convexity, as on application of the flat glass plate, produced a larger set of primary rings than could be had by any of the former experiments. This apparatus was still farther improved, by painting two of the sides of the prism black, so as to exclude all extraneous light; by which means I could easily perceive that those fringes (which were produced by rings of about three quarters of an inch diameter,) extended from one end of the prism to the other, that is, to an extent of at least seven or eight times the diameters of the rings, and it is uncertain how much farther they might have extended with a longer prism. They were also seen parallel to the edges of the prism, by carrying the eye in that direction, either to the right or left.

Nor do these rings or fringes cross each other undisturbed, for the prismatic colours of the rings, where they intersect each other, are deranged from their natural order; and the division lines of the fringes, where they intersect the other intersections, are drawn into a zig-zag form, but beyond those intersections they proceed in straight lines. These several intersections produce a most beautiful appearance of chequer, or rather net work, the meshes of which assume the hexagonal form, resembling the cups of a honeycomb; of which it is impossible to convey an adequate idea without seeing the experiment.

*Exp.* 6. Having discovered unexpectedly these phenomena from one set of primaries and its reflected image, I was induced to try what effect could be produced by two sets of

primaries brought into a similar situation with respect to each other. For this purpose, a double convex lens, of about thirty-six inches focus, was laid on a flat piece of looking-glass plate, having its under side painted black; on the lens was placed another piece of plane glass plate; by these means two sets of primary rings were produced, whose positions with respect to each other could be varied at pleasure. On using the shadow of the black card I was agreeably surprized to find, that instead of parallel *fringes* a new species of prismatic *rings* appeared, whose number and sizes varied with the positions and distances of the two sets of primaries; their dimensions were from two to three times the diameters of the primaries from which they appeared to originate, sometimes only one set appeared, sometimes two, and at other times a third very faintly.

On first observing these new rings, it was found, that on moving the eye in a horizontal direction to the right or left, they sometimes moved *with*, and sometimes contrary to the motion of the eye; others were stationary, although the eye moved; also, that sometimes the prismatic colours were seen in the usual order, and at other times inverted; all of which facts seemed not a little perplexing at that time; but their causes will be better understood from what follows.

*Exp.* 7. By a subsequent experiment, it was discovered, that those rings towards the circumference of the new sets had their colours always in the usual order; but that those nearest the centres had their colours always inverted; that the number of rings of each class were equal: that they all passed through the several intersections of the two primary sets of rings with each other, from which intersections they

seemed to originate; that the dividing ring between the classes, passed through a point, whose distance from the centre of each primary set was in proportion to its largest diameter.

This will be better understood by referring to fig. 2. pl. VII. where A and B are the primary sets of rings: C will represent one of the newly discovered sets, which were denominated *intersectionaries* * from their apparent origin. The fourth ring from the centre will be the division between the two classes. Those rings within the division having the red on their *insides*, and those without having the red on their outsides, as represented by the figure; where the same rule has been observed in shadowing these rings, as was observed with respect to the parallel fringes in fig. 1, namely, that the shaded side represents the violet, and the unshaded side the red of each ring, and the dark lines the divisions between them.

Admitting that parallel fringes are necessarily rectilinear, in consequence of being drawn through intersections of circles that are perfectly equal in dimensions, it follows, that where two sets of circles differ in dimensions, the corresponding intersections cannot lie in straight lines, but must necessarily be circular, as will appear evident on inspection of the figure; where the dividing ring D E could not pass through the several intersections in the points 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, unless it were circular: the same thing will hold true of all the other rings of the intersectionary set.

It also appears by the foregoing experiments, that rectilinear fringes and intersectionary rings are coloured exactly alike, and are alike divided into two classes with respect to the order of the colours. There is also an exact similarity in

* The best apology for using a new word is, that it expresses a new idea.

the reticulated crossings before mentioned, whether the sets of primaries by which they are caused, are equal or unequal in dimensions. Fringes and intersectionary rings, therefore, differ in no other respect than as right lines and circles; it is, therefore, a fair conclusion, that the phenomena of rectilinear fringes, formed between two sets of rings of equal magnitudes, are bent into rings when the two corresponding sets are unequal in magnitude.

There is also an infinite variety in the dimensions of those intersectionary rings, according as the diameters of the primaries differ more or less, being *least* where that difference is *greatest*, and increasing in size as the two sets of primaries approach to equality, until at last they end in straight lines. The dimensions of these intersectionaries will also (*cæteris paribus*) diminish as the two sets of primaries approach each other, and enlarge as these are separated; and, like Newtonian rings, enlarge or diminish with the less or greater elevation of the eye. It will be easy to conceive from inspection of fig. 4, (pl. VIII.) that where an intersectionary set of rings is formed between two sets of primaries of unequal magnitudes, it must necessarily appear on the side towards the smaller of the two primaries; which agrees with actual experiment.

The above hypothesis accounts for one set of intersectionaries; but experiment shows that if one set appears, it is almost always accompanied by a second, sometimes equal, but oftener unequal in dimensions, as in fig. 3, (pl. VIII.) at other times part of a third set appears as segments of circles only. It would, therefore, seem that they are formed not only between primary sets, but also between primaries combined with either

transmitted or reflected sets, provided the two, between which they are formed, are unequal in dimensions.

*Exp.* 8. The four sets of rings represented in fig. 3, (pl. VIII.) were produced by an arrangement consisting of two convex lenses laid on each other, and a piece of plane looking-glass plate laid on the uppermost lens. The large imperfect set, whose centre is at D, was evidently produced by the intersections of the two primary sets, A and B, (the former was observed to have a dark and the other a light centre), but the set whose centre is at C cannot be accounted for on the same principle; but may be owing to another cause, which will be better understood by a future experiment.

Notwithstanding these intersectionaries seem to owe their origin to a few rings only, adjoining that which divides the two classes; yet they are always filled up to the centre with prismatic colours; unless when very large, as that whose centre is at D, (fig. 3. pl. VIII.) or when they appear in part only, as segments of circles; in which case the central spaces appear blank.

*Exp.* 9. It is perfectly certain that these intersectionary rings are always formed between the two contiguous surfaces of the two lower pieces of glass when three pieces are employed; this is easily proved by the test of the shadow. But if four or more pieces are laid on each other, the number of spectra may be increased indefinitely, and these again may be multiplied by internal reflections; so that to pursue these phenomena through all the varieties of which they are capable would be an endless task.

Let it be observed here, that the several drawings of pris-

matic rings in figures 1, 2, 3, (plates VII. VIII.) are such as would appear to the eye, could it see them at right angles to the plane in which they are formed; but as the eye cannot well see them in this position, nor until it is lowered to an obliquity of about thirty degrees, the proper allowance must be made; for such rings will always appear of elliptical forms, less or more elongated according to the greater or less elevation of the eye. See fig. 4. (pl. VIII.)

*Exp.* 10. Finding from the foregoing experiments, that two sets of rings of equal magnitudes produced straight fringes, and that those of unequal sizes produced rings; it was obvious that both fringes and rings might be considered as diagonals to the angles in which they were formed. It was, therefore, concluded from analogy, that if primary fringes could be produced between two flat pieces of looking-glass plate, and that if two of those sets were made to cross each other, a set of straight or rectilinear fringes should be formed diagonally between them; and, on making the experiment, I had the pleasure to find the result precisely answered expectation. So far theory and experiment agreed (see fig. 6, pl. VIII.); but in the course of making this and some of the succeeding experiments, several unexpected phenomena were discovered.

*Exp.* 11. The slips of plate glass used in this and several of the following experiments were from four to six inches long, and about one and a half inch broad, their edges having been ground straight.

On wiping two of those glass slips perfectly clean with soft shammy or a soft dry linen rag, (which is absolutely necessary, as the smallest particle of dust, scarcely perceptible even with a microscope, interposed between the slips,

would prevent the success of the experiment), and by applying two of their ends together, and by using some friction and a considerable degree of pressure, a beautiful set of rectilinear prismatic coloured fringes appeared across the glass slips, having all the prismatic colours in the same order as Newtonian rings, and equally vivid, (see fig. 5, pl. VIII.) and although the breadths of those fringes could be increased or diminished by the greater or less degree of pressure (which had the effect of diminishing or increasing the angle formed by the planes), yet their breadths continued to be uniform, or as nearly so as might be expected, considering the unavoidable imperfections of the best plate glass.

It was proved by Sir ISAAC NEWTON, that primary prismatic rings were repeated at equal increments of interval between two spherical surfaces, because the semi-diameters (or, which is the same thing, the diameters) of those rings were found on actual measurement to be to each other as the *square roots* of the series, 0, 2, 4, 6, 8, &c. beginning at the centre of the rings or point of contact, as must be well known to mathematicians; it might, therefore, have been known by reasoning *a priori*, that if similar prismatic phenomena could be produced between two flat planes, the corresponding repetitions must take place at regular and equal intervals from the point of contact, or vertex of the angle, corresponding to the natural numbers of which the measurements of the rings express the square roots; that is, as the series 0, 2, 4, 6, 8, &c. The principle is, therefore, fully confirmed by this experiment.

*Exp.* 12. Those primary fringes have also transmitted sets between them, alternate in colours to their primaries, exactly similar to Newtonian rings; for, by placing them longitudi-

nally in the direction of the light, and by using the shadow of a black card thrown across them, both primaries and transmitted fringes may be seen at once by the naked eye. Let the light come in the direction AB in fig. 5, pl. VIII. and let CD represent the edge of the shadow next the light, those fringes above the line CD are primaries, and those below it are transmitted sets, alternate in colours to the others. Although these primary fringes are uniform in their breadths, they are not quite so with respect to colour; for the yellow, blue, indigo, and violet, are predominant in the first, second, and third fringes next to the place of contact, although these four colours are but little perceived after the third fringe, where ten are seen, the red, orange, and green being predominant in all the rest.

*Exp.* 13. After having produced one set of primary fringes, I succeeded in having another set formed at right angles thereto, by applying a third slip of glass longitudinally to the upper one of the first two, on which the expected diagonal fringes immediately appeared in the angle between the two primary sets, as shown in fig. 6, pl. VIII. where B and C are the primary fringes, and D the intersectionary set divided into two classes, as shown by the dotted line.

*Exp.* 14. It was found by trials, that the relative position of two sets of fringes, when formed by three slips only of glass plates, connected together as in Experiment 12, could not be changed at pleasure; but, by using four slips, and having a set of fringes formed between each pair, which were unconnected, these could be placed the one over the other in any position, and at any required angle; by this arrangement, it was discovered, that whatever was the magnitude of the angle

formed by the two sets of primaries, that angle was always bisected by the central band of the intersectionaries. And although these latter evidently proceed from the crossings of the two sets of primaries, yet they are never continued through those crossings to the opposite angle at A, fig. 6, (pl. VIII.) nor could they be made to appear in any angle formed by primary fringes, unless the said fringes were so disposed as to have their red sides turned inwards, or towards each other. This remarkable fact was proved by several repetitions of the same experiment.

*Exp.* 15. In the course of making these experiments, I had accidentally left a single slip of glass on one of the pairs between which a set of primaries were formed, without any other pressure than its own weight; on examining the apparatus a few minutes afterwards, I was agreeably surprised to find no less than four sets of the same kind of fringes which appeared in the angle between the two sets of primaries, as before related in Experiment 12, almost parallel to each other, and nearly so to the primaries, and at about an inch distant in front thereof. (see fig. 5. pl. VIII.) The set marked 2, had broader fringes, more vivid in colour, and consisted of a greater number, (from fifteen to nineteen), than those sets on each side thereof; for these latter appeared to have that inferiority of colour to the principal set, that it bore to the primary set. All the four sets were by attentive observation visible to the naked eye, and were all divided into two classes by a central band, as was before observed of the others; and on application of the shadow, were found to consist of primary and transmitted fringes, precisely in the same manner as first primaries, or Newtonian rings.

A representation is shown in fig. 5, (pl. VIII.) before referred to, where the sets denoted by 1, 2, 3, and 4, may be called primaries in respect of 5, 6, 7, and 8, which, in like manner, may be denominated transmitted sets; all the space below the line CD being supposed covered with a shadow of a black card.

Not having hitherto observed these secondary fringes, except where they proceeded from intersections of primaries, it was concluded, that this was the only cause of their appearance; but, by this last experiment, I was convinced of the error of this opinion, and that they are entitled to the same rank of originality as primary fringes or Newtonian rings; and, since they are always found divided into *two* classes, I shall henceforward venture to denominate them *binaries*, which perhaps may not be an improper characteristic for the whole genus, in contradistinction to *primaries*, as it will appear in the sequel, that there are several species of the former, and at least two of the latter.

*Exp.* 16. This experiment was made to ascertain whether two slips of glass only, when the uppermost was pressed by its own weight alone, would produce binary fringes between them; and I succeeded in perceiving one set whose breadths were about one-tenth of an inch each, see fig. 9, (pl. IX.); these are best seen by clear day light; but it is also necessary to have a piece of black velvet under the lower slip, otherwise to have its under side painted black.

*Exp.* 17. In endeavouring to see these fringes mentioned in the last article by candle light, I was disappointed, but accidentally perceived others of a different species, less in breadth, but much more numerous, and by which the whole length and breadth of the glass slips were covered. These were visible

by the light of a small candle only, nor could they be perceived except in the image of the blaze of the candle reflected from the upper surface of the upper slip of glass, and by moving either the eye, or the candle, or the slips across the direction in which the fringes appeared: and even with every precaution, I sometimes failed in seeing them, which I attributed to the presence of very minute dust between the glass plates, which in some cases can be known only by its effects. Moreover, when the eye changes from a greater to a less quantity of light, it requires some time to adapt itself to such delicate and minute objects, before it can perceive them satisfactorily. See fig. 8. (pl. IX.)

*Exp.* 18. By subsequent trials it was found, by the use of an oil lamp, having five or six small wicks in a row, composed of hempen packthread, which produced a pale brownish light, that those singular fringes could be seen with nearly as much ease and certainty as any of the other phenomena, though not all at once; but, by moving the light over them, otherwise moving the slips with respect to the light, and by using a magnifying glass, it was ascertained that the specimen represented by fig. 8, (pl. IX.) contained thirty of these fringes to an inch. Being uncertain whether they might not be the same as the primary fringes mentioned in Experiment 11, or a continuation of them, I caused a few of these latter to be formed at one end of the slips at A, fig. 8, (pl. IX.) when it was found that they crossed each other at a certain angle as shown in the figure; therefore, they could not be the same. Moreover, as they have no perceptible colour like first primaries, nor are divided into classes as binaries, they must be different from either.

*Exp.* 19. It next occurred to try what effect could be

produced by three slips of glass when laid together, and pressed by their own weight alone. Leaving them in this situation about fifteen minutes, I found an irregular set of binaries spread over the surface of those slips; a representation of which is shown in fig. 9. pl. IX.

On drawing or sliding the upper piece of glass along the surface of the middle one, these fringes changed their shape, and disappeared as far as the middle slip was uncovered by the upper one; or if the upper two were kept together, and both moved over the surface of the under slip, the same phenomena took place. But if the upper glass was in the smallest degree separated from the other two, or if the two upper pieces were in the same degree separated from the lower one; in either case, the spectra first changed their shapes and then vanished; but, on leaving the slips to the pressure of their own weight, were again as instantly restored. On changing the position of these three slips by placing the two upper ones across the lower one, a new spectrum was formed as seen in fig. 10, pl. IX. In these as well as in the following figures of binaries, the central band, dividing the two classes, is always denoted by a dotted line.

These spectra may be varied almost to infinity by the smallest change of distance or relative position of any one of the three slips to the other two; and it affords a pleasing amusement to observe those fleeting forms start into new and fantastic shapes in such a manner as strongly to resemble, in miniature, the coruscations of the aurora borealis. In order to determine whether these spectra were formed between the two upper, or between the two lower surfaces of the glass slips, the test of the shadow was applied, which determined

them to be always formed between the two lower contiguous surfaces.

*Exp.* 20. But it appearing very unaccountable that the mere presence of the upper glass slip should produce spectra between the two lower slips; I wished to have the fact corroborated by another experiment. For this purpose two similar slips of glass were so closely applied together, as to produce primary fringes between them; and in this position they were cemented together with bees' wax, to prevent shifting: this double slip being substituted, instead of the two upper unconnected slips in Experiment 12, produced binaries as usual. On application of the shadow, the primaries appeared in the second, and the binaries in the third shadow, as expected; but it being perfectly certain that the primaries were formed between the two upper contiguous surfaces, and as the shadow proved that the thickness of one slip of glass was interposed between the two spectra, there could not remain a doubt of the binaries being formed between the two lower contiguous surfaces.

*Exp.* 21. These results being so unexpected with three slips, it naturally occurred to me, to try what effect four would produce. Having placed two, laid together horizontally on a table, I took up the double slip mentioned in Experiment 18, in order to clear it of dust, and was in the act of holding it up between the light and the eye, in order to examine whether it was perfectly clean; and it happening accidentally to be in the direction of the two lying on the table, I was agreeably surprised to find a spectrum already appear, as if formed in the air, although the two pairs of slips were several inches asunder; which spectrum, on moving the

double slip in the hand, out of the direction of those on the table, vanished as far as those on the table were uncovered by those in the hand. And notwithstanding this spectrum appeared to be formed in the air, the test of the shadow proved it to be formed between the two slips on the table; and although it was visible when the two pairs of slips were not less than ten inches asunder, it could not be perceived except through the medium of the double slip held in the hand.

A representation of this experiment is shown in fig. 11, pl. IX. where AB is a section of the two slips held in the hand; and CD of those on the table. Fig. 12 pl. IX. represents one of those fleeting and fantastic forms as seen by the eye at F in this experiment.

*Exp.* 22. If the result of the last experiment appears extraordinary and unaccountable, the present one will appear still more so; for, on lowering the double slip in the hand from its former elevation of about 45 degrees, to about 15 degrees, so that its image was seen reflected from the upper surface of the upper glass on the table, as represented by GH in fig. 13. pl. IX., a new spectrum, fig. 14, pl. IX. was seen in this reflected image, superadded to that shown in fig. 12, which was not to be perceived in the object A B itself! Both spectra together, as seen by the eye at F, are represented in fig. 15.

*Exp.* 23. It was fully ascertained by the test of the shadow, that while the double slips were in the position described in Experiment 20, both spectra were formed between the two slips on the table; but, on lowering the two upper slips until they were laid flat on those incumbent on the table, both

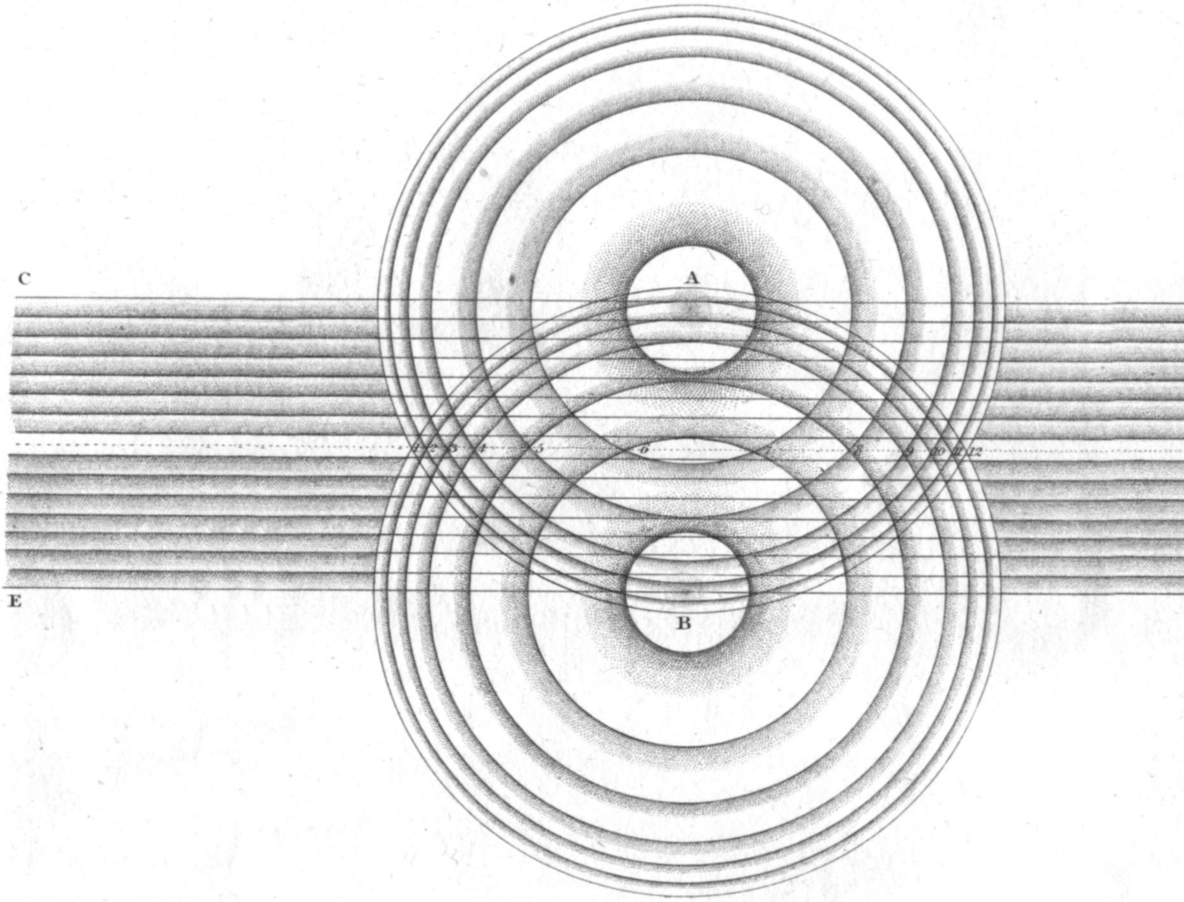
were gradually metamorphosed into two others; one of which was formed between the two lower, and the other between the two middle slips brought into contact by this new arrangement; this was also proved by the test of the shadow. It may be worthy of remark, that in every variety of shape assumed by these spectra, the binary characteristic is clearly visible in them all.

*Exp.* 24. On viewing a set of Newtonian rings, as described in Experiment 4, through one of the double slips, while in the position fig. 11. pl. IX, the apparatus forming the rings being on the table; a set of narrow binary rings appeared, concentric to the primaries, and near to the edge of the lenses: and on lowering the double slip to the second position, fig. 13. pl. IX., another set of binary rings appeared in the reflected image of the double slip, also concentric to the primaries, but consisting of broader rings, though less in diameter than those of the first set; and all these three sets were seen distinctly, at one and the same time.

The two sets of binary rings, seen in this experiment, correspond to the two irregular spectra in experiment 20; and since the rings must have been formed between the lenses on the table (because no *rings* are ever formed unless between surfaces, one of which at least is spherical), this affords a corroborating proof, that the irregular spectra seen in Experiment 20, although apparently formed in the air, were really formed between the two slips of glass lying on the table.

The above results differ so widely from any that have hitherto been published, that it is allowable to doubt, whether they can be accounted for on the common and received

*Fig. 1.*



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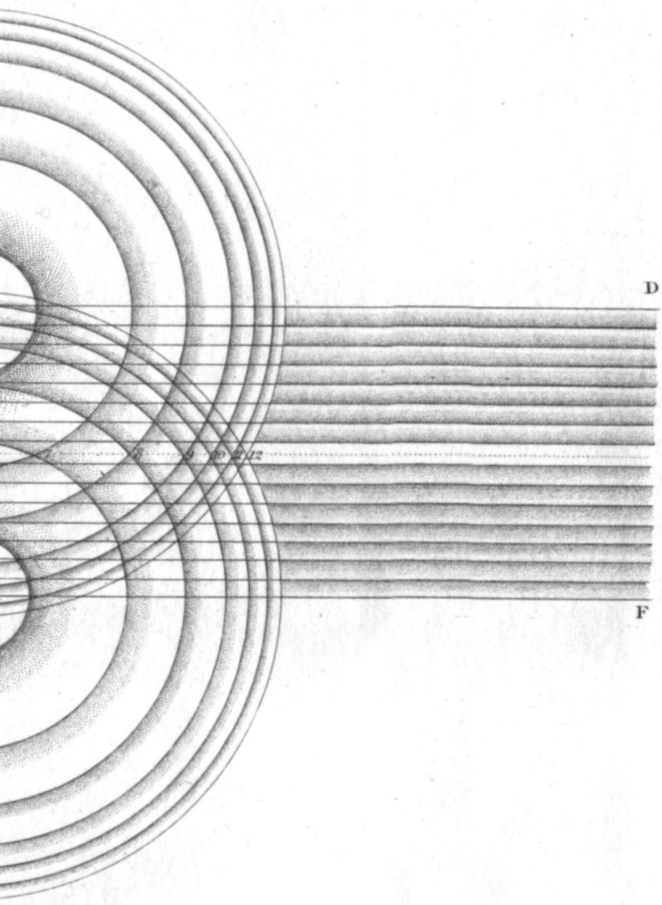
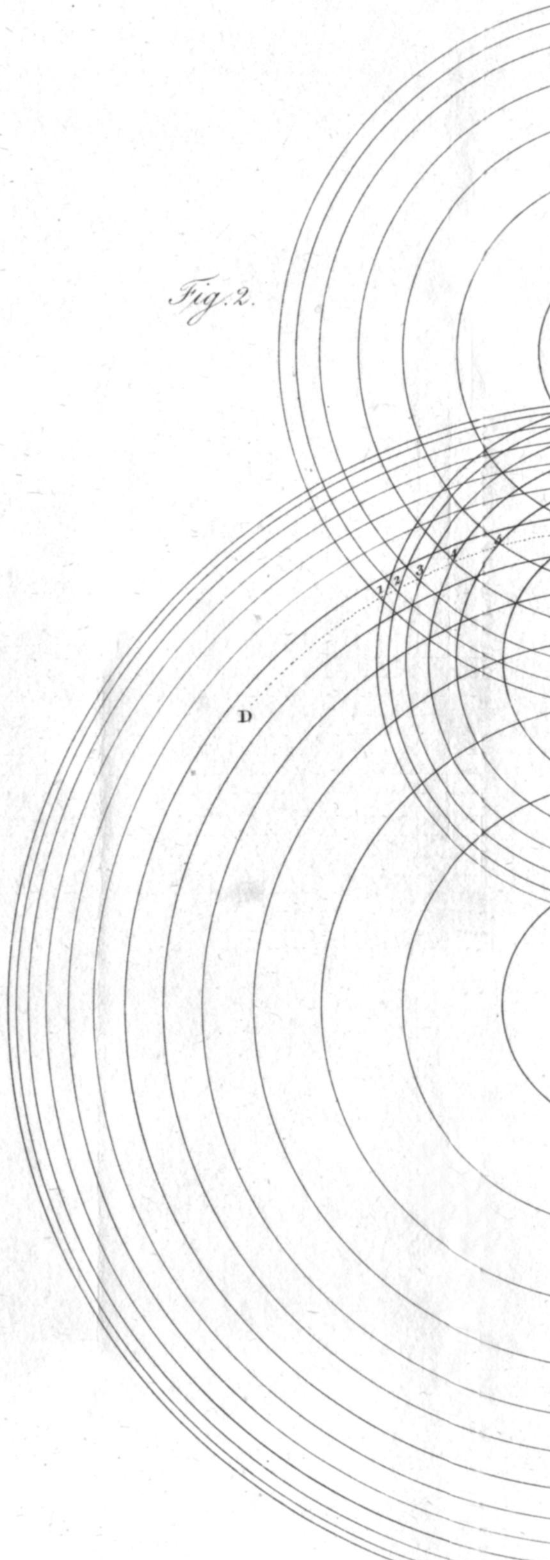



Fig. 2.



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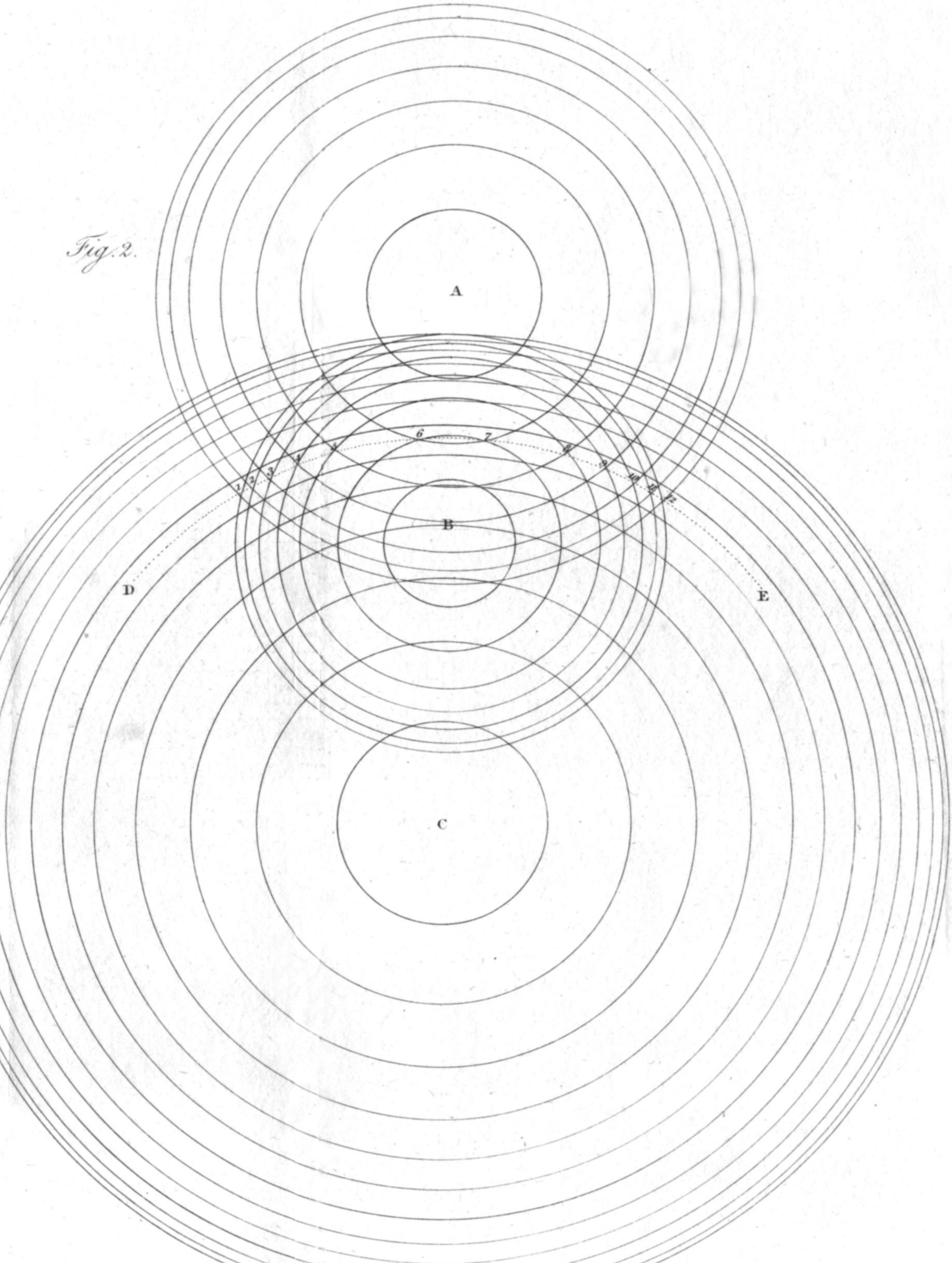
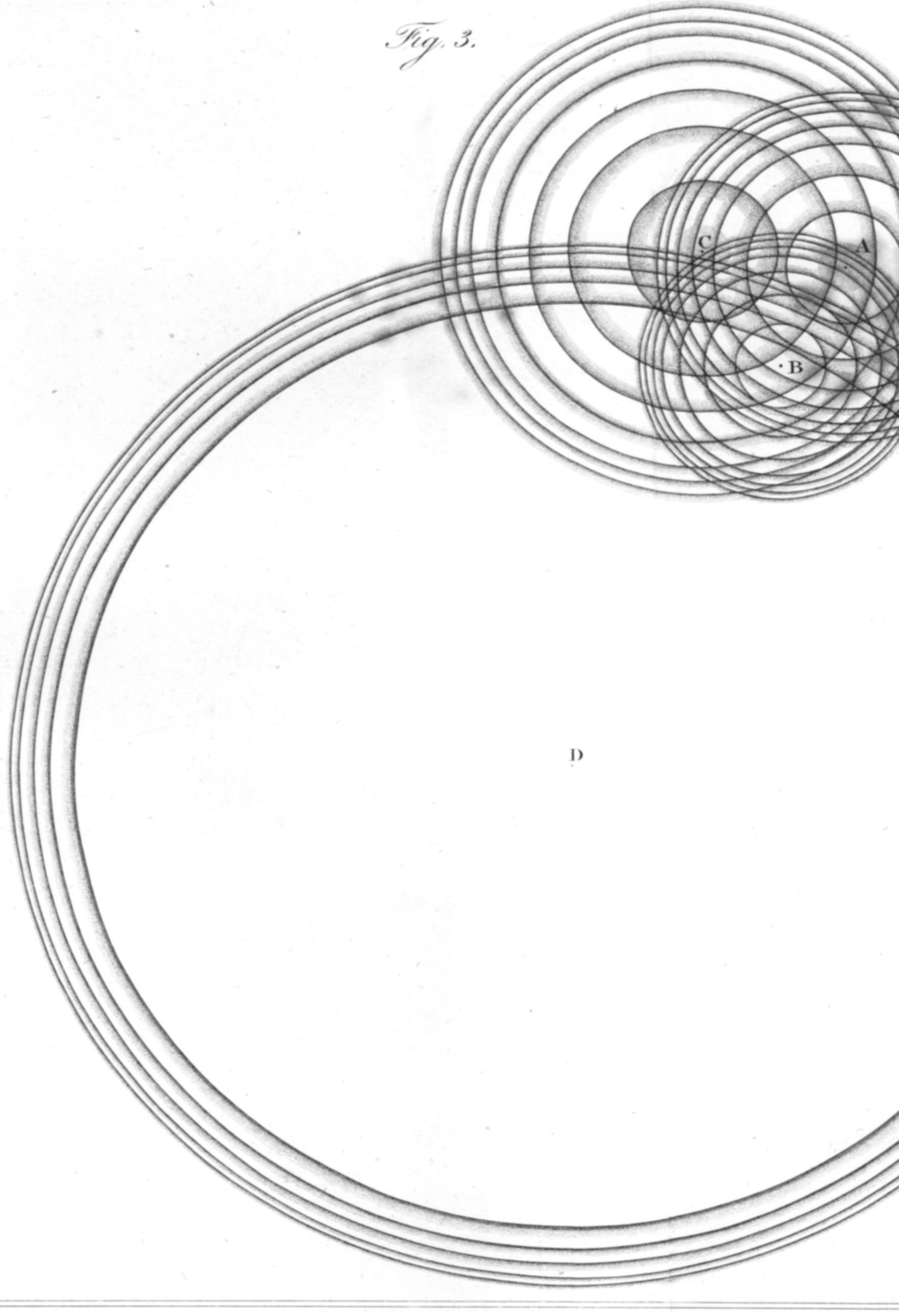


Fig. 3.



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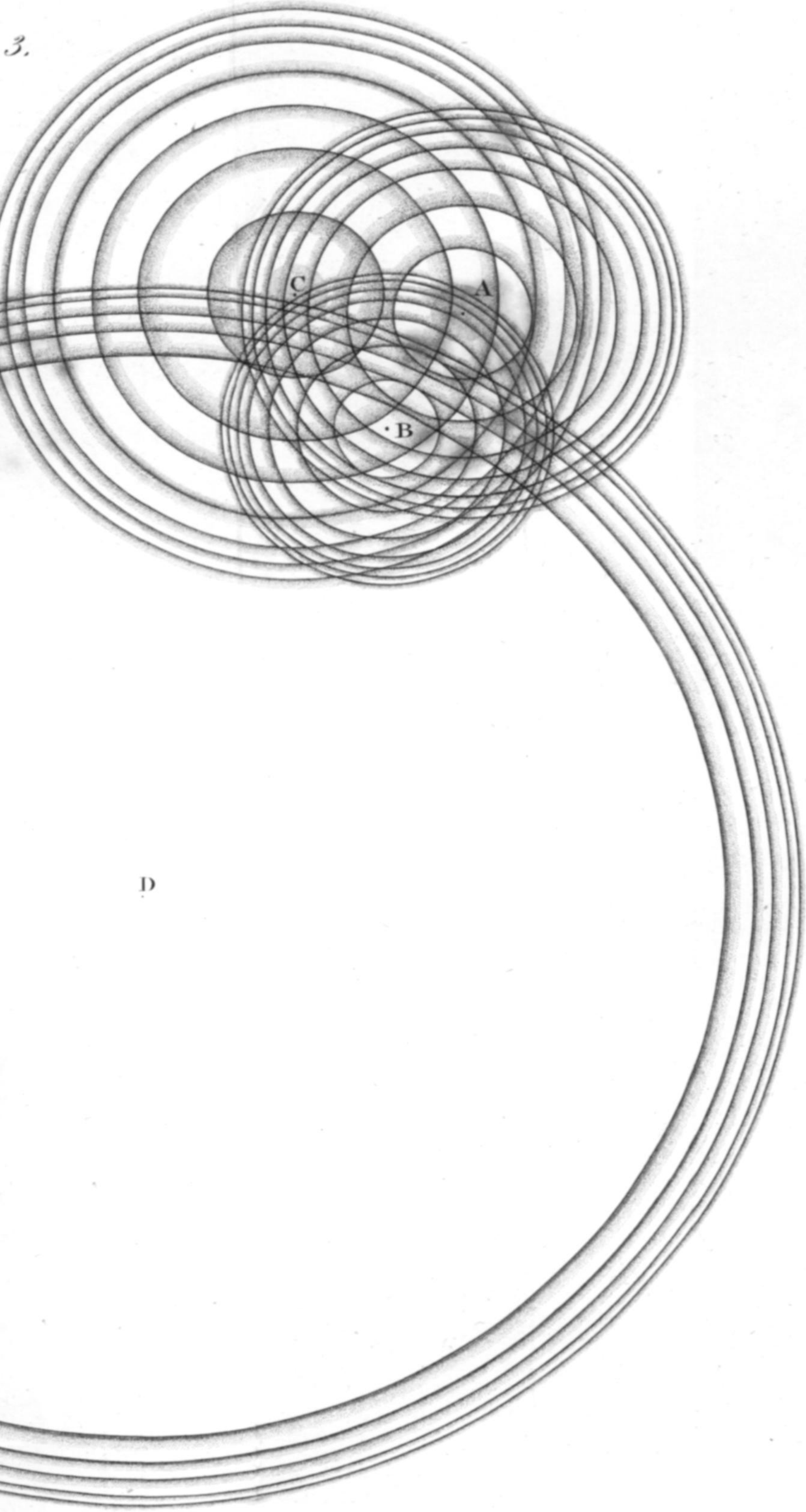
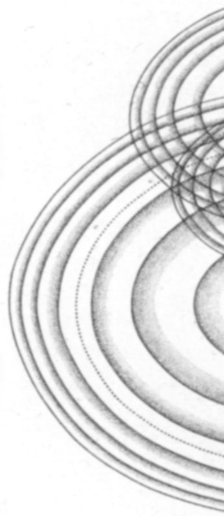
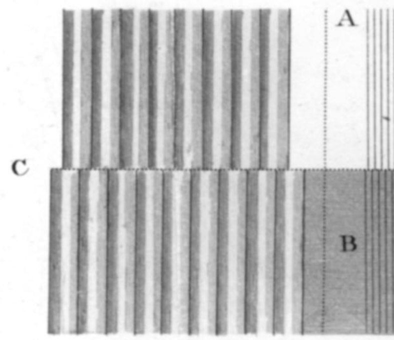




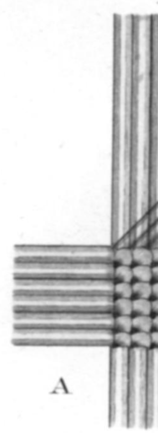



*Fig. 4.*

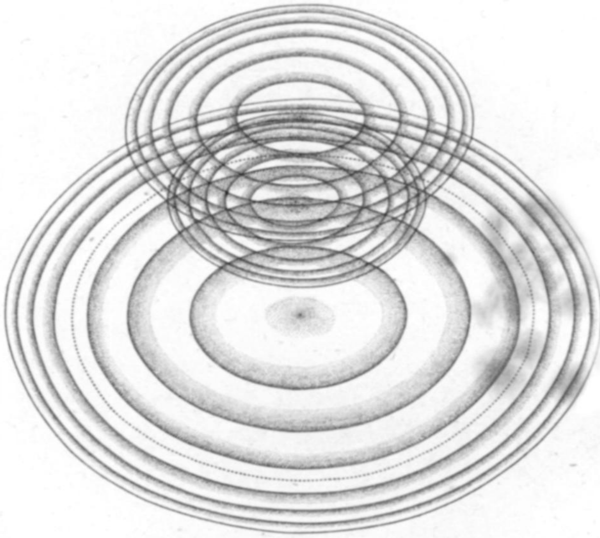


*Fig. 5.*

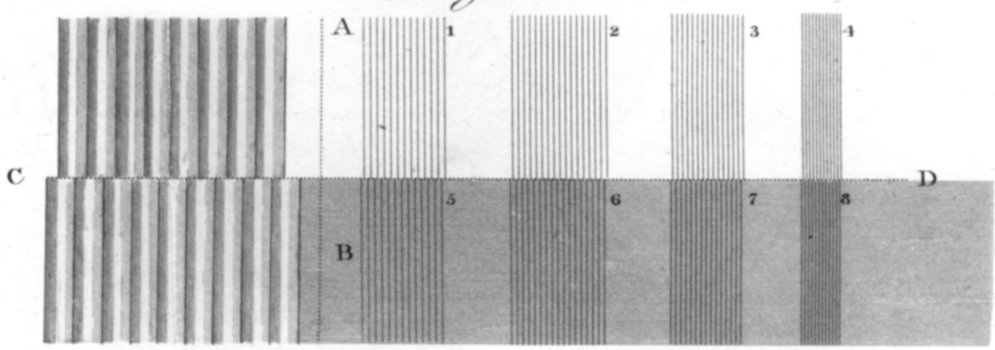
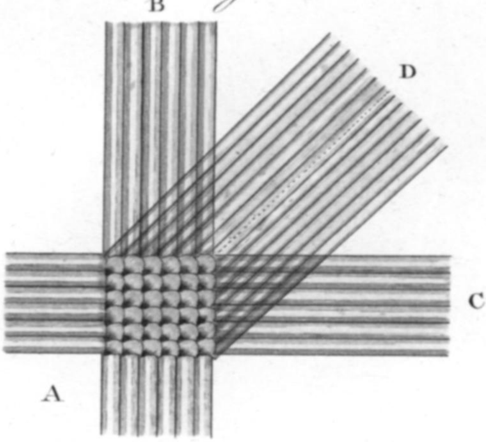
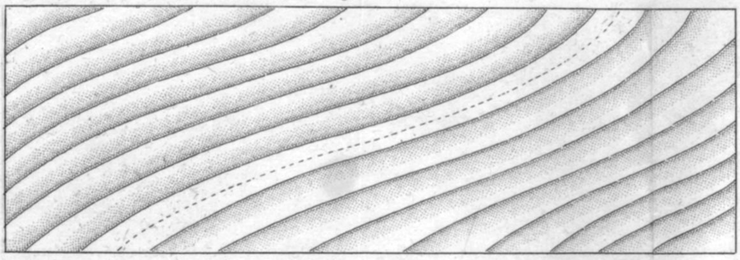



*Fig. 6.*




*J. Basire sc.*

Fig. 7.



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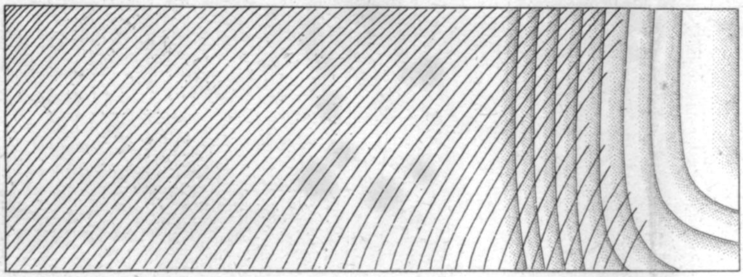

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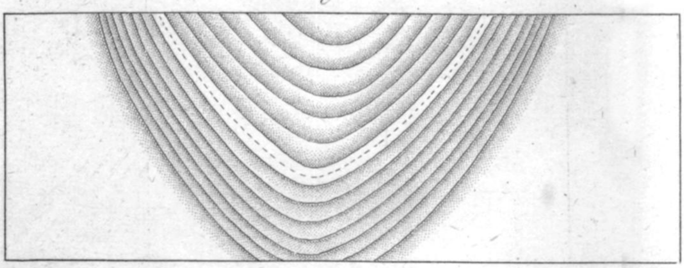

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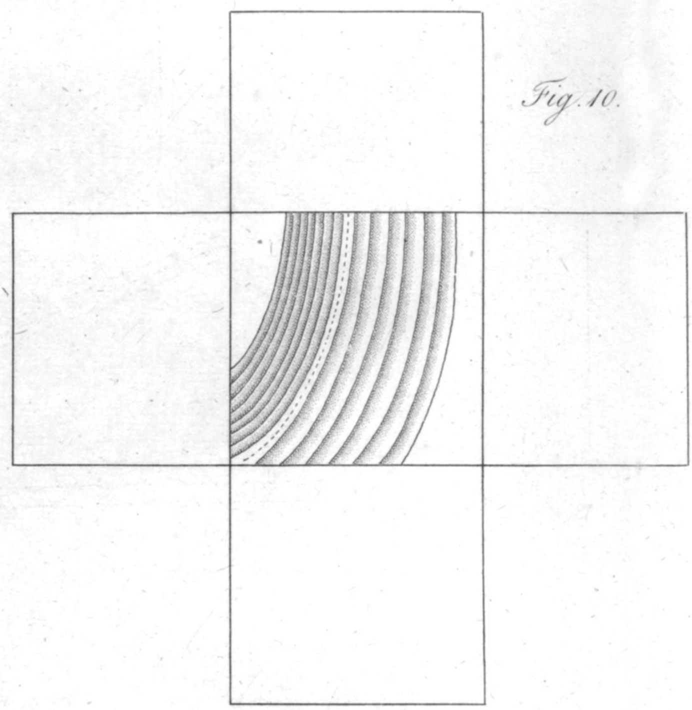


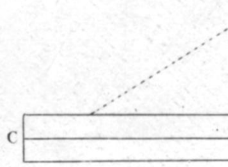
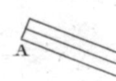



Fig. 12.

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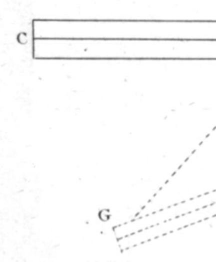

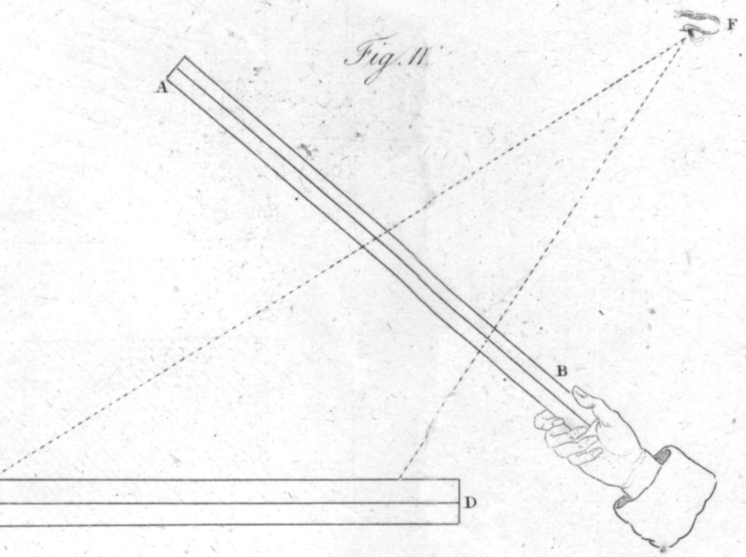


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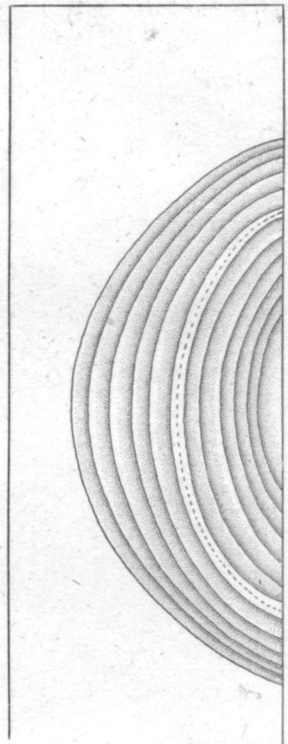

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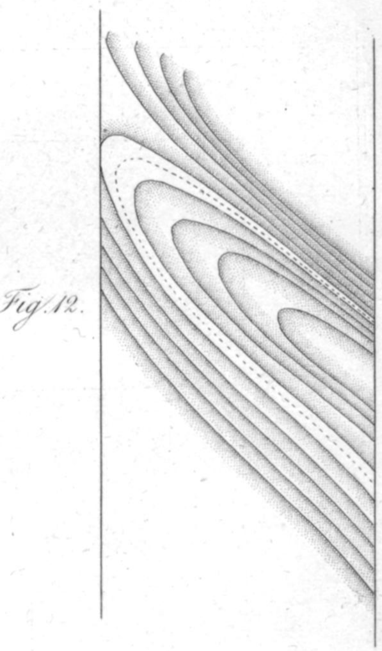

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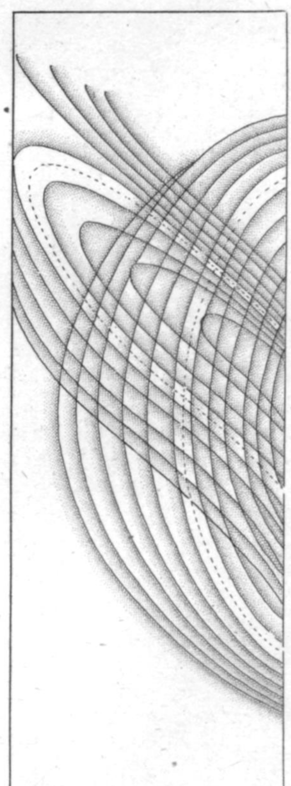

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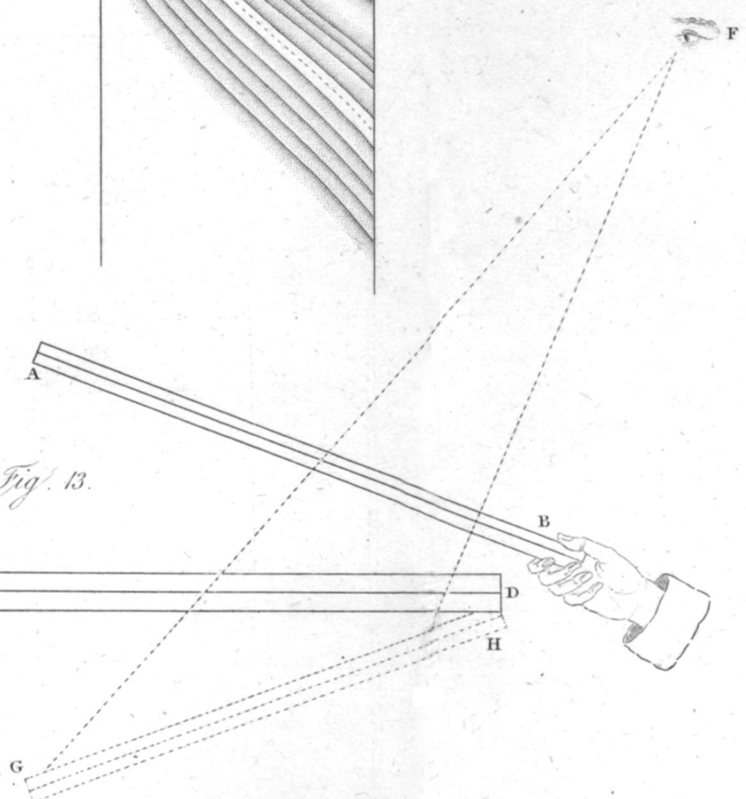
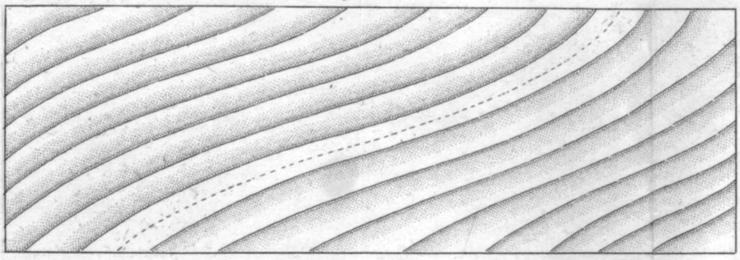



Fig. 13.

Fig. 7.



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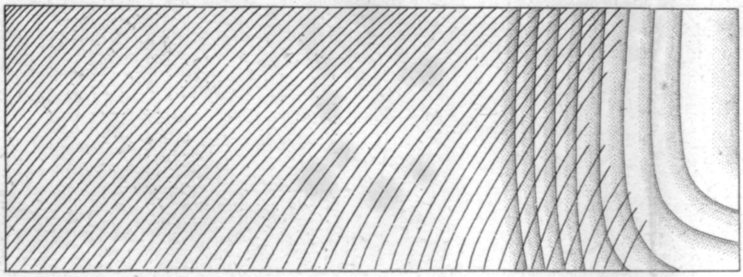

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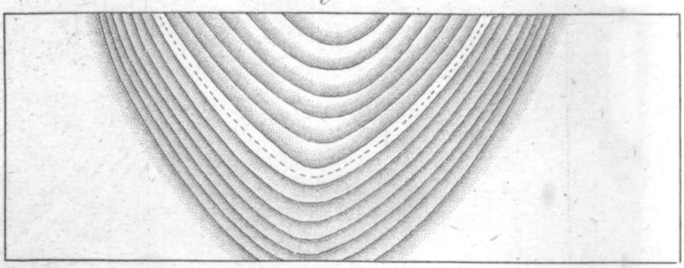

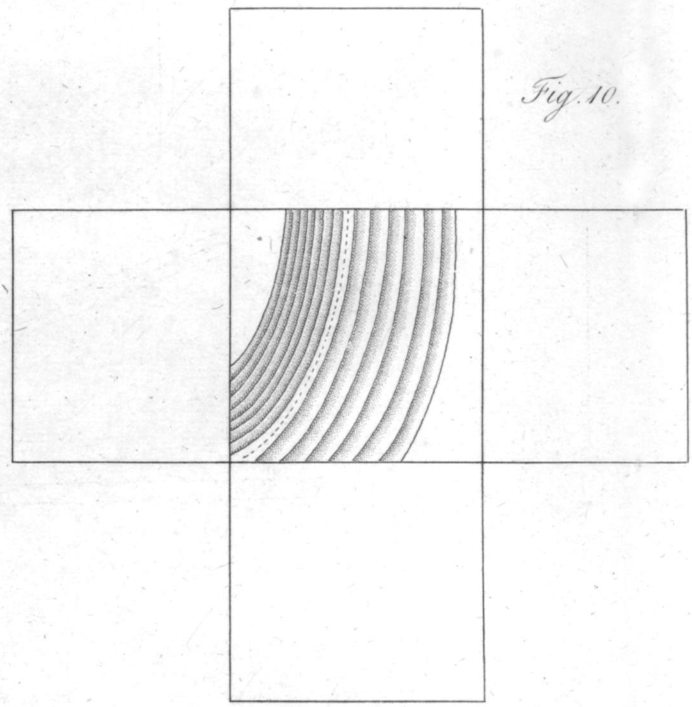

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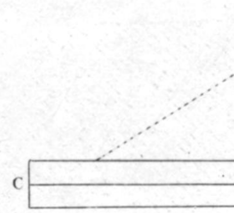



Fig. 12.

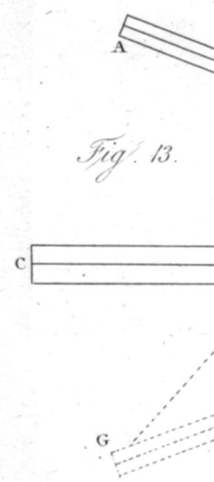
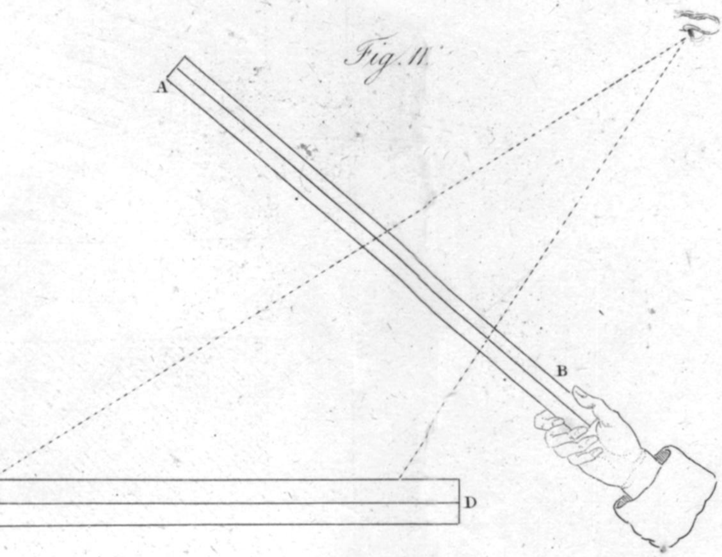



Fig. 13.

Fig. 11.

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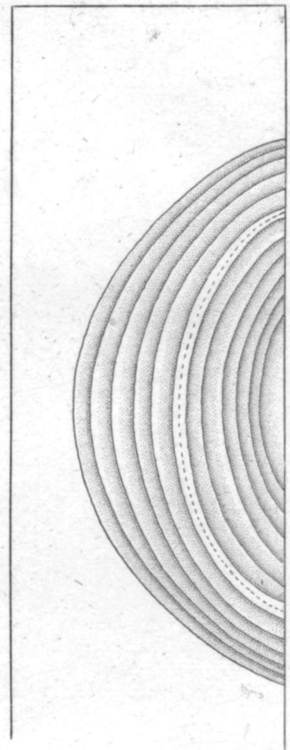

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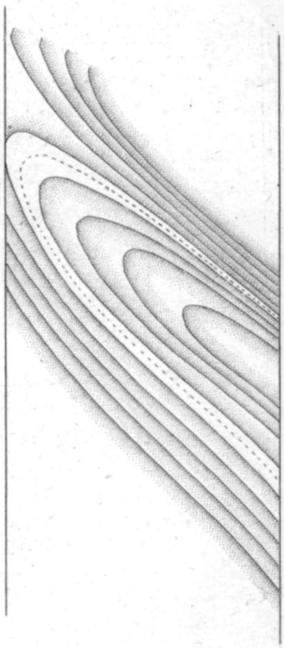

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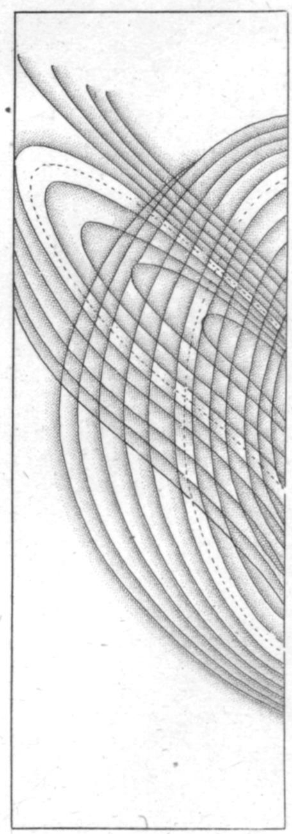
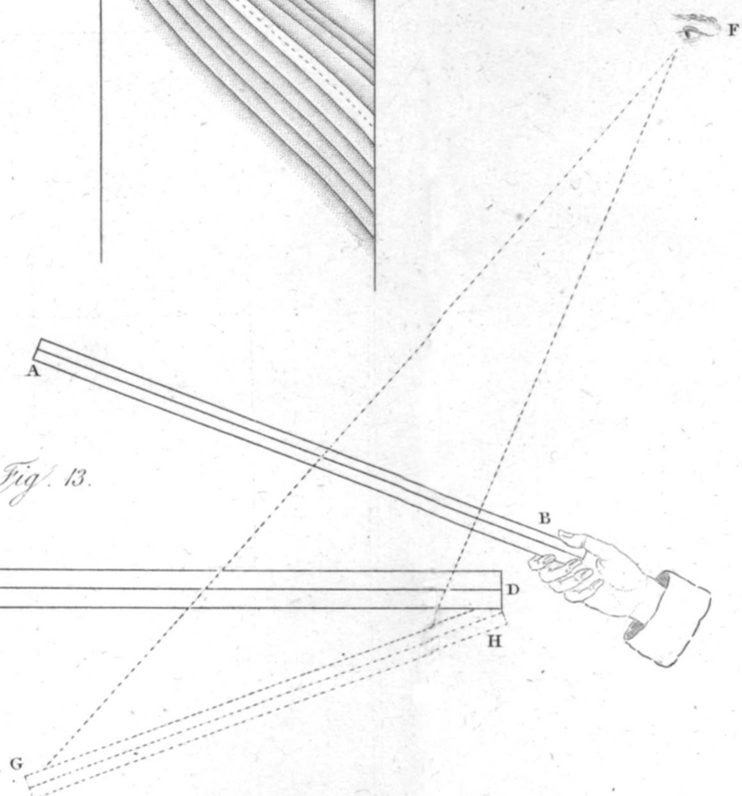


Fig. 13.

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principles of physical optics, unless perhaps the newly discovered principle, which has been denominated the *polarity* of the rays of light, may serve to explain their causes. However, "as every desideratum may be considered as an imperfect discovery," which when completed may lead to others of still greater importance; and as the subject is so far from being exhausted, that perhaps we are only entering on a new career of discoveries, not only in optics, but in every other branch of natural knowledge; in this point of view, the prospect before us is rendered as extensive as it is animating and delightful.

JOHN KNOX.

*Belfast, Oct.* 6, 1812.